LENS BARREL

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application relates to the following U.S. Patent Applications, all filed concurrently herewith on September 24, 2001, and all of which are expressly incorporated herein by reference in their entireties: "ZOOM LENS MECHANISM" having attorney docket No. P21180, "ZOOM LENS MECHANISM" having attorney docket No. P21181, "ECCENTRICITY-PREVENTION MECHANISM FOR A PAIR OF LENS-SUPPORTING RINGS" having attorney docket No. P21182, "REDUCTION GEAR MECHANISM" attorney docket No. P21183, "RING MEMBER SHIFT MECHANISM AND LENS GROUP SHIFT MECHANISM" having attorney docket No. P21184, "LENS BARREL" having attorney docket No. P21186, "LENS BARREL" having attorney docket No. P21187, "LENS BARREL" having attorney docket No. P21188, "ZOOM LENS BARREL" having attorney docket No. P21190, and "LENS BARREL" having attorney docket No. P21192, each naming as inventors Hiroshi NOMURA et al.; and "LENS DRIVE CONTROL APPARATUS FOR ZOOM LENS SYSTEM HAVING A SWITCHING LENS GROUP" having attorney docket No. P21189 and naming as inventor Norio NUMAKO.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to a lens barrel and, more particularly, to a lens barrel supporting a pair of sub-lens groups, functioning optically when in a mutually close position and in a mutually distant position.

2. Description of the Related Art

In a lens barrel constructed to support a plurality of lens groups, distances between the lens groups must be accurate. This is difficult because the distance between the lens groups is affected not only by the accuracy of the lens itself but also by the accuracy of assembly processes of the lens group frames. Accordingly, the lens distance tend to deviate from one lens barrel to another. While this deviation in the distances may be avoided by providing an adjustment mechanism, provision of such additional mechanisms inevitably leads to larger construction of the lens barrel and an increase in manufacturing costs. Also, adjusting actual distances in each lens barrel is inefficient.

For example, the assignee of the present application has proposed an unprecedented zoom lens system that meets the contradictory demands of high zoom ratio and

miniaturization (U.S. Patent Application No.09/534,307, Japanese Patent Application No. Hei 11-79572). This zoom lens system has the following characteristics: it includes a plurality of movable lens groups for varying the focal length; at least one of the lens groups is a switching lens group which includes two sub-lens groups, one of the sub-lens groups being a movable sub-lens group that can be selectively positioned at either one movement extremities in the optical axis direction with respect to the other sub-lens group; the movable sub-lens group of the switching lens group is positioned at an extremity of a short-focal-length zooming range, from the short focal length extremity to an intermediate focal length, and at the opposite extremity of a long-focal-length zooming range, from the intermediate focal length to a long focal length extremity; and zoom paths of the switching lens group and the other lens groups are discontinuous at the intermediate focal length and are defined to focus on a predetermined image plane corresponding to the position of the movable sub-lens group. There may be one or more intermediate focal lengths.

In the mechanical structure of the lens barrel for use in such a zoom lens system, it is desirable to prevent

deviation in distance between the sub-lens groups without using an adjustment mechanism in order to avoid a large and complicated switching lens group unit construction, since mechanisms for moving the sub-lens groups toward and away from each other are provided in the support barrel for the switching lens group, which forms a single lens group.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to achieve a lens barrel having a simple construction that can prevent deviation in the distance between the first sub-lens group and the second sub-lens group, wherein the first and second sub-lens groups function optically when in a mutually close position and in a mutually distant position.

In order to achieve the above-mentioned object, a lens barrel includes a front sub-lens group provided on the object side and a rear sub-lens group provided on the image side, the front and rear sub-lens groups functioning optically when in a mutually close position and in a mutually distant position with respect to the optical axes of the front and rear sub-lens groups; a front sub-lens group frame for supporting the front sub-lens group and a rear sub-lens

group frame for supporting the rear sub-lens group, the front and rear sub-lens group frames being held in engagement with each other while being able to move in the optical axis direction relative to each other; a lens frame shift mechanism for causing the front sub-lens group frame and the rear sub-lens group frame to move relative to each other to obtain the mutually close position and the mutually distant position; a first lens group positioning surface, provided on the front sub-lens group frame, for positioning the front sub-lens group in the optical axis direction by contacting a portion of a rear surface of the front sub-lens group upon the front sub-lens group being inserted from the front side of the front sub-lens group frame; and a second lens group positioning surface, provided on the rear sub-lens group frame, for positioning the rear sub-lens group in the optical axis direction by contacting a portion of a front surface of the rear sub-lens group upon the rear sub-lens group being inserted from the rear side of the rear sub-lens group frame.

In an embodiment, the front sub-lens group frame includes a front sealed region in the front end portion thereof, the front sealed region preventing the front sub-lens group from coming out from the front side of the

front sub-lens group frame. The rear sub-lens group frame includes a rear sealed region in the rear end portion thereof, the rear sealed region preventing the rear sub-lens group from coming out from the rear side of the front sub-lens group frame.

Preferably, the lens barrel further includes a pair of follower engaging recesses which are formed on one of opposing surfaces of the front sub-lens group frame and the rear sub-lens group frame; and a follower projection which are formed on the other of the opposing surfaces of the front sub-lens group frame and the rear sub-lens group frame. The mutually close position of the front sub-lens group is defined via engagement of the follower projection and one of the pair of follower engaging recesses, and the mutually distant position of the front sub-lens group is defined via engagement of the follower projection and the other of the pair of follower engaging recesses.

Preferably, the front sub-lens group frame and the rear sub-lens group frame can be rotated relative to each other. The lens frame shift mechanism includes a shift cam mechanism provided on opposing surfaces of the front sub-lens group frame and the rear sub-lens group frame for moving the front and rear sub-lens group frames to the

mutually distant position and to the mutually close position in accordance with the relative rotation of the front and rear sub-lens group frames.

Preferably, the shift cam mechanism includes a shift cam surface provided on one of the opposing surfaces of the front sub-lens group frame and the rear sub-lens group frame, the shift cam surface being inclined with respect to a circumferential direction thereof; and a follower projection provided on the other of the opposing surfaces of the front sub-lens group frame and the rear sub-lens group frame for engaging with the shift cam surface.

Preferably, a pair of follower engaging recesses are formed at opposite ends of each of the shift cam surfaces, wherein the follower projection engages with one of the follower engaging recesses when the front and rear sub-lens group frames are in the mutually close position and in the mutually distant position.

Preferably, the front and rear sub-lens groups form one of a plurality of variable lens groups of a zoom lens system that are moved in the optical axis direction during zooming, the front and rear sub-lens groups serving as a focusing lens group when in the mutually close position and in the mutually distant position. The lens barrel includes

a focusing mechanism for moving the front and rear sub-lens group frames in the mutually close position and in the mutually distant position, in the optical axis direction, while maintaining a constant distance between the front and rear sub-lens group frames.

The present disclosure relates to subject matter contained in Japanese Patent Application No. 2000-289388 (filed on September 22, 2000) which is expressly incorporated herein in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic drawing of a first embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 2 is a schematic drawing of a second embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 3 is a schematic drawing of a third embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 4 is a schematic drawing of a fourth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 5 is a schematic drawing of a fifth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 6 is a schematic drawing of a sixth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 7 is a schematic drawing of a seventh embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 8 shows one example of stopping positions of the lens groups when a photographic operation is carried out, to which the present invention is applied.

Figure 9A shows an example of the stopping positions of Figure 8 and an example of an actual zoom path of the lens groups, to which the present invention is applied.

Figures 9B and 9C depict an additional schematic view

of the concepts shown in Figs. 8 and 9A.

Figure 10 is a cross-sectional view showing an embodiment of a zoom lens barrel which includes the zoom lens systems having switching lens groups shown in Figures 1, 8 and 9.

Figure 11 is a developed view of an inner surface of a cam ring of the zoom lens barrel of Figure 10 showing an exemplary arrangement of cam grooves.

Figure 12 is an exploded perspective view showing components of a switching lens group frame of the zoom lens barrel.

Figure 13 is an exploded perspective view showing some of the components of the switching lens group frame of the zoom lens barrel.

Figure 14 is a perspective view showing a different assembly of some of the components of the switching lens group frame of the zoom lens barrel.

Figure 15 is a cross-sectional view of an upper half of the switching lens group in which a first sub-lens group and a second sub-lens group are in a mutually distant position at the wide-angle extremity.

Figure 16 is a cross-sectional view of an upper half of the switching lens group in which the first sub-lens group

and the second sub-lens group are in a mutually close position at the telephoto extremity.

Figure 17A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the mutually distant position at the wide-angle side and are focused on an object at infinity.

Figure 17B is a developed view showing the components of Figure 17A in actual engagement.

Figure 18A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the mutually distant position at the wide-angle side and are focused on an object at a minimum distance.

Figure 18B is a developed view showing the components of Figure 18A in actual engagement.

Figure 19A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the mutually close position at the telephoto side and are focused on an object at infinity.

Figure 19B is a developed view showing the components of Figure 19A in actual engagement.

Figure 20A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the mutually close position at the telephoto side and are focused on an object at a minimum distance.

Figure 20B is a developed view showing the components of Figure 20A in actual engagement.

Figure 21 is an exploded view illustrating how the mutually close position of the first sub-lens group and the second sub-lens group on the telephoto side switches to/from the mutually distant position on the wide-angle side via the rotation of an actuator ring.

Figure 22 illustrates how focusing is carried out by the actuator ring.

Figure 23 is an enlarged expanded view showing a face cam of a first sub-lens group frame.

Figure 24 is an enlarged developed view showing the relationship of the first sub-lens group frame, the second sub-lens group frame, and the actuator ring with respect to a front shutter retaining ring.

Figure 25 is a front view showing the relationship between the first sub-lens group frame and the front shutter retaining ring when viewed in a direction of the arrows

indicated by a line XXV-XXV in Figure 14.

Figure 26 is a partially enlarged view showing an encircled portion indicated by XXVI in Figure 25.

Figure 27 is a front view showing the relationship between the second sub-lens group frame and the front shutter retaining ring when viewed in a direction of the arrows indicated by the line XXVII-XXVII in Figure 14.

Figure 28 is a partially enlarged view showing an encircled part XXVIII in Figure 27.

Figure 29 is a front view showing an arrangement of reduction gears of a driving system of the actuator ring, the reduction gears being retained between the front shutter retaining ring and the gear holding ring.

Figure 30 is a developed plan view of Figure 29.

Figure 31 is a block diagram showing a control system of the zoom lens barrel shown in Figure 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the embodiment described below, the present invention is applied to a lens barrel. This lens barrel is suitable for use with a zoom lens system proposed by the assignee of the present application in the U.S. Patent Application No.09/534,307. U.S. Patent Application No.

09/534,307 is expressly incorporated herein by reference in its entirety.

First, embodiments of a zoom lens system with a switching lens group proposed in the U.S. Patent Application No.09/534,307 will be herein described.

Figure 1 shows the first embodiment of the zoom lens system. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a negative third lens group L3. The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front

end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. The third lens group L3 is fixed to a second lens group frame 21. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11). Throughout Figures 1 through 9, IM indicates an image plane (film surface, and so forth) which is at a predetermined position.

In the zoom paths according to the first embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), and the first sub-lens group S1 (movable sub-lens group frame 12) move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10 and the second variable lens group 20 move towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 maintains the shorter distance (second separation space/narrow space) d2 with respect to the second sub-lens group S2; and the first variable lens group 10 and the second variable lens group 20 move towards the object, based on the positions thereof which are determined at the intermediate focal length fm, after the first through third lens groups L1 through L3 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 1. It should be noted, however,

that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Figure 2 shows the second embodiment of the zoom lens system. The zoom lens system includes a positive first variable lens group 10, a positive second variable lens group 20, and a negative third variable lens group 30, in that order from the object side. The first variable lens group 10 includes a positive first lens group L1. The second variable lens group 20 includes a negative second lens group L2 (first sub-lens group S1) and a positive third lens group L3 (second sub-lens group S2), in that order from the object side. The third variable lens group 30 includes a negative fourth lens group L4. The first lens group L1 is fixed to a first lens group frame 11. The second sub-lens group S2 of the second variable lens group 20 is fixed to a second lens group frame 21. The first sub-lens group S1 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move, in the optical axis

direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. The fourth lens group L4 is fixed to a third lens group frame 31. A diaphragm D is arranged to move together with the second variable lens group 20 (second lens group frame 21).

In the zoom paths according to the second embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the third variable lens group 30 (third lens group frame 31), and the first sub-lens group S1 (movable sub-lens group frame 22) move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11), the second variable lens group

20 (second lens group frame 21) and the third variable lens group 30 (third lens group frame 31) move towards the object side while mutually changing the distances therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10, the second variable lens group 20 and the third variable lens group 30 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 23, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2; and the first variable lens group 10, the second variable lens group 20 and third variable lens group 30 move towards the object side based on the positions thereof which are determined at the intermediate focal length fm, after the first through fourth lens groups 1 through 4 have been moved towards the image side, while changing the distances therebetween.

The zoom paths for the first variable lens group 10, the second variable lens group 20 and the third variable lens group 30 are simply depicted as straight lines in Figure 2. It should be noted, however, that actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the second variable lens group 20 (second lens group frame 21) regardless of the zooming range.

Likewise with the first embodiment, the zoom paths are discontinuous at the intermediate focal length fm; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first lens group L1, the first sub-lens group S1 (second lens group L2) and the second sub-lens group S2 (third lens group L3) and the fourth lens group L4 respectively at the short focal length extremity fw, the intermediate focal length fm (discontinuous line) and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 3 shows the third embodiment of the zoom lens system with a switching lens system. In this embodiment,

the first lens group L1 is constructed so as to have negative refractive power, which is the only difference compared with the second embodiment. Apart from this characteristic, the third embodiment is substantially the same as the second embodiment.

Figure 4 shows the fourth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4 (fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the

first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the fourth embodiment, the first variable lens group 10 (first lens group frame 11),

the second variable lens group 20 (second lens group frame 21), the first sub-lens group S1, and the third sub lens group S3 move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance d3 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2, and

also the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the intermediate focal length fm, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 4. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the

second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through third embodiments, in the fourth embodiment, the zoom paths are discontinuous at the intermediate focal length fm; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal length extremity fw, the intermediate focal length fm (discontinuous line), and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 5 shows the fifth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2),

in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4 (fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along

a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the fifth embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the first sub-lens group S1, and the third sub lens group S3 move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to a first intermediate focal length fm1, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance d3 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame

21) move towards the object side while mutually changing the distance therebetween.

[B] At the first intermediate focal length fm1, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moved toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2.

[C] In an intermediate zooming range Zm from the first intermediate focal length fm1 to a second intermediate focal length fm2, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the longer distance d3; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the first intermediate focal length fm1, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance

therebetween.

[D] At the second intermediate focal length fm2, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the intermediate zooming range Zm; and the third sub-lens group S3 moves to the image-side movement extremity of the guide groove 23, wherein the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[E] In a long-focal-length zooming range Zt from the second intermediate focal length fm2 to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the second intermediate focal length fm2, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 5. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through fourth embodiments, in the fifth embodiment, the zoom paths are discontinuous at the first intermediate focal length fm1 and the second intermediate focal length fm2; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3) and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal length extremity fw, the first and second intermediate focal lengths fm1, fm2 (discontinuous line), and the long focal length extremity ft. According to such a zoom path, a

miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 6 shows the sixth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4 (fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes

into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the sixth embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the first sub-lens group S1, and the third sub lens group S3 move in following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to a first intermediate focal length fm1, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance d3 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the first intermediate focal length fm1, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the short-focal-length zooming range Zw; and the third sub-lens group S3 moves to the image-side movement extremity of the guide groove 23, and wherein the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[C] In an intermediate zooming range Zm from the first intermediate focal length fm1 to a second intermediate focal

length fm2, the first sub-lens group S1 and the second sub-lens group S2 maintain the longer distance d1 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the first intermediate focal length fm1, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

[D] At the second intermediate focal length fm2, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the intermediate zooming range Zm; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, and wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2.

[E] In a long-focal-length zooming range Zt from the second intermediate focal length fm2 to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2

therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the second intermediate focal length fm2, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 6. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through fifth embodiments, in the sixth embodiment, the zoom paths are discontinuous at the first intermediate focal length fm1 and the second intermediate focal length fm2; however, a solution for

continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal length extremity fw, the first and second intermediate focal lengths fm1, fm2 (discontinuous line), and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 7 shows the seventh embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a positive first lens group L1 (first sub-lens group S1), a negative second lens group L2 (second sub-lens group S2) and a positive third lens group L3 (third sub-lens group S3), in that order from the object side. The second variable lens group 20 includes a negative fourth lens group L4. The first sub-lens group S1 and the third sub-lens group S3 are fixed to a first lens group frame 11. The second sub-lens

group S2 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The second sub-lens group S2 is selectively moved to either the object-side movement extremity at which the movable sub lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. The fourth lens group L4 of the second variable lens group 20 is fixed to a second lens group frame 21. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the seventh embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), and the second sub-lens group S2 move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a shorter distance therebetween;

however, the second sub-lens group S2 and the third sub-lens group S3 maintain a longer distance therebetween; and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while changing the distance therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the second sub-lens group S2 moves to the image-side movement extremity of the guide groove 13, and wherein the second sub-lens group S2 moves away from the first sub-lens group S1 and moves toward the third sub-lens group S3.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the longer distance therebetween, and the second sub-lens group S2 and the third sub-lens group S3 maintain the shorter distance therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the intermediate focal

length fm, after the first through fourth lens groups L1 through L4 have been moving towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 7. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 through the third sub-lens group S3, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through sixth embodiments, in the seventh embodiment, the zoom paths are discontinuous at the intermediate focal length fm; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth lens group L4, respectively, at the short focal length extremity fw, the intermediate focal length fm, (discontinuous line), and the

long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

As can be understood from the above description, it is practical to apply the above-described zoom lens system having switching lens groups to a photographing lens system of a camera in which the photographing lens system and a finder optical system are independently provided. Moreover, with respect to each of the first through fourth lens groups L1 through L4, stopping positions at which the lens group stops upon zooming are preferably determined in a stepwise manner along a fundamental zoom path, i.e., it is preferable to provide a plurality of focal-length steps. Figures 8 and 9 show zoom lens systems in which positions for stopping each lens group are determined in a stepwise manner along the fundamental zoom paths. Since these zoom lens systems are the same as that of the first embodiment, identical components are provided with the same designators. The zoom paths are depicted with fundamental dotted lines; and positions at which the first lens group frame 11 and the second lens group frame 21 stop are indicated with black dots along the dotted lines. Further, in Figure 9A, the dots are connected by smooth (continuous) curved lines to form an

actual zoom path. The actual mechanical structure thereof allows the first lens group frame 11 and the second lens group frame 21 to be moved along the smooth curved lines (actual zoom path).

In the first through seventh embodiments, each lens group is illustrated as a single lens element; however, a lens group can of course include a plurality of lens elements.

Figures 9B and 9C depict an additional schematic view of the concepts shown in Figs. 8 and 9A. It should be noted in the following explanation that Figures 9B and 9C are schematic in nature (e.g., not to scale and/or not depicting actual shape) and that one skilled in the art will recognize that the zoom paths are not necessarily straight, and the manner in which the schematics of Figs. 9B and 9C relate to a designed (zooming) cam groove shape (which will differ depending at least on the optical configuration). As shown in Fig. 9B and 9C, if, in order to arrange movement in accordance with Fig. 9A, it is determined that one zoom path will be connected in an uninflected line (i.e., essentially without discontinuity or inflection and without switching), then the cam ring, shape, and orientation of cam groove(s) can be adapted for this purpose. As shown in Fig. 9B, each

of the three fundamental zoom paths can include a discontinuity. By smoothly connecting one zoom path, in this case the second zoom path (e.g., depicted in the Figures 9B and 9C by shifting all of the zoom paths in the intermediate-to-telephoto range "up" so that the path of the second lens group is connected), it becomes possible to carry out the movements of the combined groups more simply. In this case, it is decided to use "switching" for the first group and a smooth inflection in the second group. As noted, the stepwise movement/positioning and prohibition of photography in the switching/inflection range also form part of this system.

Although Fig. 9C depicts a shift in which the second zoom path is made essentially connected, the amount of shifting "up" does not need to fully align the curve to be made smoother, but need only take up a portion of the discontinuity (e.g., reducing any inflection to a selected amount, such as an imperceptible amount). In the following description, it is noted that cam groove 44f is essentially without discontinuity or inflection, relating to the second group zoom path in Figs. 9A-9C, and that cam groove 44r has a small inflection, relating to the third group zoom path in Figs. 9A-9C. However, the adaptation depicted in Figs.

9B and 9C can be used for any of the systems depicted in Figs. 1-7 or variations thereof.

It can be decided to use at least one smooth or uninflected line for various reasons, including simplicity of movement, simplicity of manufacturing, or to improve exterior appearance of movement of lens barrels (e.g., to avoid visible discontinuity in the operation of the lens barrels, so that an unsophisticated operator does not become concerned about the proper operation of the camera). In the example given, the movement of the lens barrel supporting the second lens group is essentially continuous, while the switching movement of the first lens group and the inflected movement of the third lens group cannot be seen from the exterior of the camera.

In each of the above-described embodiments, the first variable lens group 10 in Figures 1, 8, and 9A-9C, the second variable lens group 20 in Figure 2, the second variable lens group 20 in Figure 3, the first variable lens group 10 in Figure 4, the first variable lens group 10 in Figure 5, the first variable lens group 10 in Figure 6, and the first variable lens group 10 in Figure 7 (including the first lens L1 and the third lens L3 as a unit) are each switching lens groups which serve as focusing lens groups in any focal

length range.

A preferred embodiment will now be described in which the present invention has been applied to the zoom lens barrel in the examples shown in Figures 1, 8, and 9A-9C, which have a first variable lens group 10 (switching lens group) and a second variable lens group 20.

Figures 10 through 31 show an embodiment of a zoom lens barrel (system). Unlike the zoom lens systems shown in Figures 1, 8 and 9, in which one of the first and second sub-lens groups S1 and S2, which together form a switching lens group 10, is fixed to the first lens group frame 11, the first and second sub-lens groups S1 and S2 in this embodiment are both movable with respect to the switching lens group frame in the optical axis direction. In this embodiment, a moving path of the switching lens group frame upon zooming and a path of the first sub-lens group S1 and the second sub-lens group S2 within the switching lens group frame can be added to each other to give a composite zoom path, which corresponds to the zoom path shown in Figures 1, 8, and 9A-9C. Upon focusing, the first sub-lens group S1 and the second sub-lens group S2 are integrally moved within the switching lens frame in the optical axis direction. In a photographic operation, the first sub-lens

group S1 and the second sub-lens group S2 are placed at a predetermined position, before the release of the shutter is started, as a result of the movement of the switching lens group frame and the movement of the first sub-lens group S1 and the second sub-lens group S2 within the switching lens group frame in accordance with focal length information set by an operator (the photographer) and object distance information detected.

As shown in Figure 10, a stationary barrel 42, which is fixed to a camera body 41, has a female helicoid 43 formed on an inner surface of the stationary barrel 42. A male helicoid 45, which is formed on the rearmost circumference of a cam ring 44, engages with the female helicoid 43. Arranged outside of the stationary barrel 42 is a pinion 47 which is rotated by a zooming motor 46. Gear teeth (not shown) are formed on the circumference of the cam ring 44 wherein a part of the male helicoid 45 is cut out therefor. The gear teeth, which are formed to have the same oblique direction as the lead of the male helicoid 45, engages with the pinion 47. Accordingly, the cam ring 44 advances or retreats along the optical axis direction when the cam ring 44 is rotated in either direction by the zooming motor 46 due to the engagement of the female helicoid 43 and male

helicoid 45. The position of the cam ring 44 resulting from the rotation made by the zooming motor 46 is detected by focal length detecting device 46C, which can include, for example, of a code plate and a brush.

A linear guide ring 48 is supported by the cam ring 44. The guide ring 48 rotates relative to the cam ring 44 and moves together with the cam ring 44 along the optical axis direction (i.e., no relative displacement is allowed in the optical axis direction). The guide ring 48 is supported by a camera body 41 in a manner that enables the guide ring 48 to move only in the optical axis direction. Arranged inside of the cam ring 44 in order from the front side of the cam ring 44 are a switching lens group frame 50 (first lens group frame) which supports the first variable lens group 10 (i.e., the first sub-lens group S1 and second sub-lens group S2) and a second lens group frame 49 which supports the second variable lens group 20. The switching lens group frame 50 and the second lens group frame 49 are linearly guided along the optical axis direction by the guide ring 48.

Cam grooves 44f and 44r are formed on an inner surface of the cam ring 44. The cam grooves 44f and 44r receive the switching lens group frame 50 and second lens group frame

49, respectively. Figure 11 shows an arrangement of the cam grooves 44f and 44r in a developed view. Three sets of the cam grooves 44f and 44r are formed circumferentially with each groove spaced at equi-angular distances from one another. Radial follower pins 50p and 49p are provided on the switching lens group frame 50 and the second lens group frame 49 to be received in the cam grooves 44f and 44r, respectively.

The cam grooves 44f and 44r include introducing portions 44f-a and 44r-a for the follower pins 50p and 49p, retracted portions 44f-r and 44r-r for the zoom lens system, wide-angle extremity portions 44f-w and 44r-w, and telephoto extremity portions 44f-t and 44r-t, respectively. A rotational angle θ_1 is defined as the rotational angle from the introducing portions 44f-a and 44r-a to the retracted portions 44f-r and 44r-r, respectively. A rotational angle θ_2 is defined as the rotational angle from the retracted portions 44f-r and 44r-r to the wide-angle extremity portions 44f-w and 44r-w, respectively. A rotational angle θ_3 is defined as the rotational angle from the wide-angle extremity portions 44f-w and 44r-w to the telephoto extremity portions 44f-t and 44r-t, respectively. A rotational angle θ_4, defined as the rotational angle beyond

the telephoto extremity portions 44f-t and 44r-t, which serves as a rotational angle for assembly use. Each of the cam grooves 44r for the second lens group frame 49 has an intermediate discontinuous position fm that corresponds to the zoom path of the second variable lens group 20 as described in the embodiments in Figures 1, 8 and 9.

In contrast, no discontinuous position appears to exist in the cam grooves 44f for the first variable lens group 10 between the wide-angle extremity portion 44f-w and the telephoto extremity portion 44f-t since the change in shape (profile) of each cam groove 44f is smooth in this area. This is because, in this embodiment, the switching lens group frame 50 and the sub-lens group S2 are moved in such a manner that the positions of the sub-lens group S2 are not discontinuous in the short-focal-length zooming range Zw and in the long-focal-length zooming range Zt, the two ranges extending on both sides of intermediate focal length fm in Figure 1. A connection line CC is schematically shown in Figure 1. The connection line CC connects the zoom path of the short-focal-length zooming range Zw to zoom path of the long-focal-length zooming range Zt, the two ranges extending on both sides of the intermediate focal length fm. The cam groove 44f is shaped to correspond to the zoom path

connected by the connection line CC. As the follower pin 50p moves along a section corresponding to the connection line CC, the sub-lens group S1 moves from the object-side movement extremity to the image-side movement extremity. It is necessary to control the zoom lens barrel so that the section of the cam groove 44f corresponding to the line CC is not used as an actual zooming range in a photographic operation (i.e., the cam ring 44 is not stopped). Alternatively, the cam grove 44f can include the discontinuous position similar to that of the cam groove 44r.

In the above-described zoom lens barrel, the cam ring 44 advances or retreats along the optical axis while rotating as the pinion 47 is rotated via the zooming motor 46 in either direction, which causes the switching lens group frame 50 (i.e., the first variable lens group 10) and the second lens group frame 49 (i.e., the second variable lens group 20), which are guided in the optical axis direction within the cam ring 44, to move in the optical axis direction along a predetermined path defined by the cam grooves 44f and 44r.

Novel features of the present embodiment reside in a support structure by which the first sub-lens group S1 and

the second sub-lens group S2 are supported in the switching lens group frame 50 and the driving structure thereof. A particular example of an arrangement within the switching lens group frame 50 will now be described by reference to Figures 12 through 31.

As shown in Figures 15 and 16, a front shutter retaining ring 51, a rear shutter retaining ring 52, a first sub-lens group frame 53, a second sub-lens group frame 54, an actuator ring 55, and a gear holding ring 56 are arranged within the switching lens group frame 50. The front shutter retaining ring 51, the rear shutter retaining ring 52, and the gear holding ring 56 form a portion of the switching lens group frame 50. The first sub-lens group S1 is fixed to the first sub-lens group frame 53, and the second sub-lens group S2 is fixed to the second sub-lens group frame 54. The first sub-lens group frame 53, the second sub-lens group frame 54, and the actuator ring 55 are movably fitted in a central opening 51p (see Figure 12) of the front shutter retaining ring 51. These movable members, i.e., the first sub-lens group frame 53, the second sub-lens group frame 54, and the actuator ring 55, enable the first sub-lens group S1 and the second sub-lens group S2 to be at a mutually close position, or be at a mutually distant position, with respect to the

optical axis direction, and also enable the first sub-lens group S1 and the second sub-lens group S2 to perform focusing.

The actuator ring 55 is rotatably supported between the front and rear shutter retaining rings 51 and 52 with the rearmost portion of the actuator ring 55 being restricted by a receiving surface 52a (Figures 13, 15, and 16) of the rear shutter retaining ring 52. The actuator ring 55 is a driving member that enables the first sub-lens group S1 and the second sub-lens group S2 to become mutually close or mutually distant from each other, and enables the first and the second sub-lens groups S1 and S2 to perform focusing via the rotation thereof. The gear holding ring 56 is fixed to the front end of the front shutter retaining ring 51, and a lens shutter mechanism 57 and a diaphragm mechanism 58 are supported by the rear shutter retaining ring 52 (Figures 12, 15, and 16).

The first sub-lens group frame 53 has a cylindrical shape and has two linear guide ribs 53a on its periphery at the opposite sides thereof at an equi-angular interval of 180 degrees. A guide bore 53b is formed in the guide rib 53a. A guide rod 59 is loosely inserted (or moveably fitted) in the guide bore 53b. The rear end of the guide

rod 59 is fixed in a fixing bore 56q formed at the rearmost portion of the gear holding ring 56 while the front end of the guide rod 59 is fixed to the front surface of the gear holding ring 56 by a bracket 60 and a screw 61. A coil spring 62 is placed over each of the guide rod 59 between the bracket 60 and the guide rib 53a so that the coil spring 62 biases the first sub-lens group frame 53 toward the second sub-lens group frame 54. A U-shaped recess 56r is provided on the gear holding ring 56 so as to receive the guide rod 59 and the spring 62 (Figures 25 through 27). The recess 56r communicatively connects with the central opening 51p of the front shutter retaining ring 51. The first sub-lens group frame 53 can be connected to the front shutter retaining ring 51 by engaging the guide ribs 53a with the guide rods 59 of the front shutter retaining ring 51 at two positions, wherein the guide ribs 53a are provided on the first sub-lens group frame 53 at 180° intervals about the optical axis.

As shown in Figures 17A, 18A, 19A and 20A, the first sub-lens group frame 53 is provided with four shift leading surfaces (shift cam surfaces) 53c that are formed circumferentially at equi-angular intervals on the end-face of the first sub-lens group frame 53. Annular

light-blocking support ribs 53d (see Figure 14) are provided radially outside of the shift leading surfaces 53c over the open ends of the shift leading surfaces 53c. Figure 23 shows an enlarged expanded view of one of the shift leading surfaces 53c which is formed essentially as a straight slope having an inclination angle α with respect to a circumferential edge of the first sub-lens group 53 (i.e., with respect to a plane normal to the optical axis), and is provided with a pair of follower engaging recesses 53e and 53f on either end of the shift leading surface 53c. Each of the engaging recesses 53e and 53f is formed as a shallow V-shaped recess. The follower engaging recess 53e defines a mutually distant position on the wide-angle side and the follower engaging recess 53f defines a mutually close position on the telephoto side, of the first sub-lens group frame 53 and the second sub-lens group frame 54 (i.e., the first sub-lens group S1 and second sub-lens group S2).

As shown in Figures 17A, 18A, 19A and 20A, the second sub-lens group frame 54 is provided on its periphery with four follower projections 54a, each corresponding to each of the four shift leading surfaces 53c of the first sub-lens group frame 53. An inclined surface 54b is provided so as to correspond to the shift leading surface 53c of the first

sub-lens group frame 53, and the follower projection 54a is provided on the end of the inclined surface 54b which is the closest to the shift leading surface 53c. The tip of the follower projection 54a has a substantially semi-circular shape which is symmetrical with respect to the longitudinal axis thereof, so that the shapes of the engaging recesses 53e and 53f correspond to the tip shape of the projection 54a. Annular light-blocking support ribs 54c are radially provided on the second sub-lens group frame 54 inside the projections 54a and the inclined surfaces 54b. The shift leading surfaces 53c formed on the first sub-lens group frame 53 and the follower projections 54a formed on the second sub-lens group frame 54 together form a shift cam mechanism (of a lens group (lens frame) shift mechanism) that enables the lens-group frames 53 and 54 either be at a mutually close position, or be at a mutually distant position. As described above, the four shift leading surfaces 53c of the first sub-lens group frame 53 and the four projections 54a of the second sub-lens group frame 54 are spaced at equi-angular intervals. Accordingly, each of the surfaces can engage with its respective projection at 180° intervals of a relative rotation. Given that N is the number of the shift leading surfaces 53c or the follower

projections 54a (four, in this embodiment) and that M is the number of the guide ribs 53a of the first sub-lens group frame 53 or the number of the guide rods 59 of the front shutter retaining ring 51 (two, in this embodiment), the relationship between M and N is that M is a multiple of N, or in other words, N is a divisor of M. This relationship makes it possible to select an assembly position from among different assembly positions, so that for example, an assembly position that provides optimum optical performance can be achieved.

Furthermore, a pair of linear guide projections 54d are formed on the second sub-lens group frame 54 on the outer surface thereof. The guide projections 54d are formed at the same circumferential positions as two of the four follower projections 54a that are positioned on the periphery of the second sub-lens group frame 54 at the opposite sides thereof at an equi-angular interval of 180 degrees. Each of the guide projections 54d is formed at a position which is rearward with respect to the follower projection 54a in the optical axis direction. Also formed on the second sub-lens group frame 54 on the outer surface thereof are three lugs 54e, which are spaced at equi-angular intervals, and are positioned rearward with respect to the

guide projection 54d in the optical axis direction. As best shown in Figure 24, each lug 54e has a pair of contact surfaces N1 and N2 that are spaced apart from each other in a circumferential direction. Each lug 54e also has a smooth circular shaped end surface N3 that is symmetrical with respect to the central axis of the lug 54e extending in the middle of the contact surfaces N1 and N2.

As shown in Figure 24, a pair of rotation preventing surfaces 51a and 51b are formed on the front shutter retaining ring 51 on the inner surface thereof, in order to define the range of rotation of the second sub-lens group frame 54 relative to the non-rotating front shutter retaining ring 51, with respect to the guide projection 54d of the second sub-lens group frame 54. The rotation preventing surfaces 51a and 51b come into contact with contact surfaces M1 and M2 of the guide projection 54d, respectively, when the second sub-lens group frame 54 is rotated in either direction, thereby defining the rotational movement extremities of the second sub-lens group frame 54. A wide-angle linear guide slot 51d is defined between the rotation preventing surface 51a and a guide surface 51c which comes into contact with the contact surface M2 of the guide projection 54d. A telephoto linear

guide slot 51f is defined between the rotation preventing surface 51b and a guide surface 51e which comes into contact with the contact surface M1 of the guide projection 54d. Thus, the width of both of the wide-angle linear guide slot 51d and the telephoto linear guide slot 51f in the circumferential direction corresponds to that of the linear guide projection 54d in the same direction. Accordingly, the guide projection 54d snugly fit in the guide slots 51d and 51f so as to movable therein.

The clearance between the wide-angle linear guide slot 51d or the telephoto linear guide slot 51f and the guide projection 54d is determined smaller (stricter) than the clearance between the guide bore 53b of the first sub-lens group frame 53 and the guide rod 59. The linear guide projections 54d are provided on the periphery of the second sub-lens group frame 54 on opposite sides thereof at an equi-angular interval of 180 degrees. A pair of the wide-angle and telephoto linear guide slots 51d and 51f are provided on the front shutter retaining ring 51 so that two linear guide projections 54d can be selectively received in the wide-angle and telephoto linear guide slots 51d and 51f with respect to the rotational positions thereof (i.e., at an angular interval of 180 degrees).

The actuator ring 55 has, on the front end surface thereof, three control recesses 55a that each correspond to each of the lugs 54e of the second sub-lens group frame 54 (see Figure 22). Each of the control recesses 55a has a shape that is symmetrical with respect to the central axis extending parallel to the optical axis and includes a pair of effective surfaces 55b and 55c that respectively come into contact with contact surfaces N1 and N2. The lugs 54e of the second sub-lens group frame 54 and the control recesses 55a constitute a focusing cam mechanism of a focusing mechanism. The control recess 55a also includes a pair of focus leading surfaces 55d and 55e (focus cam surfaces) on the telephoto side and on the wide-angle side, respectively. The focus leading surfaces 55d and 55e each come into contact with the circular end surface N3 of the lug 54e. The telephoto-side focus leading surface 55d and the wide-angle-side focus leading surface 55e are provided between the effective surfaces 55b and 55c in the form of an end-faced cam having an open front end. The slopes of the leading surfaces 55d and 55e have opposite directions with respect to the circumferential direction thereof, but have the same absolute value, i.e., the slopes both incline forwards in the optical axis direction. Annular

light-blocking support ribs 55f (see Figure 13) are provided radially outside, and over the front portion, of the control recess 55a of the actuator ring 55. The focus leading surfaces 55d and 55e, together with the lug 54e provided on the second sub-lens group frame 54, form a focus cam mechanism. As described above, the three lugs 54e of the second sub-lens group frame 54 and the three control recesses 55a of the actuator ring 55 are spaced at equi-angular intervals. In the illustrated embodiment, each of the lugs can engage with a respective recess at 120° angular intervals.

The aforementioned coil springs 62, which bias the first sub-lens group frame 53 rearward, so that the shift leading surfaces 53c contact the follower projections 54a, and the lugs 54e of the second sub-lens group frame 54 contact the telephoto side or wide-angle side focus leading surfaces 55d or 55e of the actuator ring 55. As described above, the rear end surface of the actuator ring 55 abuts the receiving surface 52a of the rear shutter retaining ring 52. Accordingly, the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the rear shutter retaining ring 52 (receiving surface 52a) can be held in contact by the sole force exerted by the coil

springs 62. As can be clearly seen from Figures 15 and 16, when the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the rear shutter retaining ring 52 are in engagement with each other, the front end of the second sub-lens group frame 54 is positioned inside the first sub-lens group frame 53, and the actuator ring 55 is situated on the periphery of the second sub-lens group frame 54.

Figure 21(A through H) shows the manner in which the first sub-lens group frame 53 and the second sub-lens group frame 54 (i.e., the first sub-lens group S1 and the second sub-lens group S2) are moved via the effective surfaces 55b and 55c between a mutually close position on the telephoto side and a mutually distant position on the wide-angle side. Note that, solid line arrows represent the rotational direction of the actuator ring 55, in Figure 21.

The arrangement shown in Figure 21(A) is the mutually distant position on the wide-angle side, in which the effective surface 55b of the actuator ring 55 abuts the lug 54e, and the linear guide projection 54d of the second sub-lens group frame 54 is disengaged from the wide-angle linear guide slot 51d. As the actuator ring 55 rotates in a clockwise direction (i.e., moves to the right in Figure

21), the effective surface 55b biases the contact surface N1 of the lug 54e to rotate the second sub-lens group frame 54 clockwise (to the right in Figure 21) until the linear guide projection 54d abuts the rotation preventing surface 51b (Figures 21(A) through 21(C)). During the rotation of the actuator ring 55 and the second sub-lens group frame 54, the first sub-lens group frame 53 (i.e., the first sub-lens group S1) follows the shift leading surface 53c, and the follower projection 54a of the second sub-lens group frame 54 so that the first sub-lens group frame 53 linearly moves closer to the second sub-lens group frame 54 (i.e., the second sub-lens group S1) (Figure 21(B)). Ultimately, the follower projection 54a engages with the follower engaging recess 53f and rearward movement of the first sub-lens group frame 53 with respect to the second sub-lens group frame 54 in the optical axis direction is stopped (Figure 21(C)). Since the follower projections 54a and the follower engaging recesses 53f are spaced at equi-angular intervals therebetween, eccentricity between the first sub-lens group frame 53 and the second sub-lens group frame 54 is prevented, with all of the projections and the recesses in engagement. This completes the switching from the mutually distant position on the wide-angle side to the

mutually close position on the telephoto side, resulting in the first sub-lens group S1 being in a mutually close position with respect to the second sub-lens group S2(i.e., mutually close extremity). Note that the actuator ring 55 cannot rotate further in this direction.

Upon completion of switching to the mutually close position on the telephoto side, the rotation of the actuator ring 55 is reversed. The lug 54e (i.e., the second sub-lens group frame 54) moves rearward following the telephoto side focus leading surface 55d until the linear guide projection 54d engages with the telephoto linear guide slot 51f. This allows the linear projection 54d to move only in the optical axis direction (Figure 21(D)). Focusing is carried out on the telephoto side from the intermediate focal length to the long focal length extremity, with the second sub-lens group frame 54 and the first sub-lens group 53 being moved integrally at the mutually close position via the telephoto side-focus leading surface 55d.

Once the actuator ring 55 is rotated until the effective surface 55c abuts the contact surface N2 of the lug 54e, the linear guide projection 54d of the second sub-lens group frame 54 disengages from the telephoto linear guide slot 51f (Figure 21(E)).

At this point, the rotation of the actuator ring 55 has been reversed (upon or after completion of the switching to the mutually close position on the telephoto side). As the actuator ring 55 rotates counterclockwise (i.e., moves to the left in Figure 21), the effective surface 55c biases the contact surface N2 of the lug 54e to rotate the second sub-lens group frame 54 leftward until the contact surface M1 of the linear guide projection 54d abuts the rotation preventing surface 51a (Figures 21(F) and 21(G)). During the rotation of the actuator ring 55 and the second sub-lens group frame 54, the first sub-lens group frame 53 follows the shift leading surface 53c and the follower projection 54a of the second sub-lens group frame 54 so that the first sub-lens group frame 53 linearly moves away from the second sub-lens group frame 54. Ultimately, the follower projection 54a engages with the follower engaging recess 53e and forward movement of the first sub-lens group frame 53 with respect to the second sub-lens group frame 54 in the optical axis direction is stopped (Figure 21(G)). Since the follower projections 54a and the follower engaging recesses 53f are spaced at equi-angular intervals therebetween, eccentricity between the first sub-lens group frame 53 and the second sub-lens group frame 54 is prevented,

with all of the projections and the recesses in engagement. This completes the switching from the mutually close position on the telephoto side to the mutually distant position on the wide-angle side, resulting in the first sub-lens group S1 being in a mutually distant position with respect to the second sub-lens group S2 (i.e., mutually distant extremity). Note that the actuator ring 55 cannot rotate further in this direction.

Upon completion of switching to the mutually distant position on the wide-angle side, the rotation of the actuator ring 55 is reversed. The lug 54e (i.e., the second sub-lens group frame 54) moves rearward following the wide-angle side focus leading surface 55e until the linear guide projection 54d engages with the wide-angle linear guide slot 51d. This allows the linear projection 54d to move only along the direction of the optical axis (Figures 21(G) and 21(H)). Focusing is carried out on the wide-angle side from the intermediate focal length to the short focal length extremity, with the second sub-lens group frame 54 and the first sub-lens group frame 53 being moved integrally at the mutually distant extremity via the wide-angle side focus leading surface 55e.

Once the actuator ring 55 is rotated until the

effective surface 55c abuts the contact surface N1 of the lug 54e, the linear guide projection 54d of the second sub-lens group frame 54 disengages from the wide-angle linear guide slot 51d, and the positions of the first sub-lens group frame 53 and the second sub-lens group frame 54 return back to the position shown at Figure 21(A).

Figure 22 shows the principle of how the focusing is carried out via the telephoto side-focus leading surface 55d and the wide-angle side-focus leading surface 55e. As the actuator ring 55 is rotated in a telephoto side focusing range pt (from an infinite photographic distance ∞ to a minimum photographic distance (object at a minimum distance) n), with the circular end surface N3 of the lug 54e in contact with the telephoto side focus leading surface 55d, the second sub-lens group frame 54 (whose rotation is confined by the linear guide projection 54d which is in engagement with the telephoto linear guide slot 51f) and the first sub-lens group frame 53 (i.e., the first sub-lens group S1 and the second sub-lens group S2) integrally moves forwardly or rearwardly along the optical axis to thereby carry out focusing. Similarly, as the actuator ring 55 is rotated in a wide-angle side focusing range pw (from an infinite photographic distance ∞ to a minimum photographic

distance (object at a minimum distance) n), with the circular end surface N3 of the lug 54e in contact with the wide-angle side focus leading surface 55e, the second sub-lens group frame 54 (whose rotation is confined by the linear guide projection 54d which is in engagement with the wide-angle linear guide slot 51d) and the first sub-lens group frame 53 (i.e., the first sub-lens group S1 and the second sub-lens group S2) integrally moves forwardly or rearwardly along the optical axis to provide focusing.

In particular, focusing on the telephoto side and focusing on the wide-angle side are achieved by controlling the number of pulses counted by a encoder 64p (see Figure 30) provided in a driving system which drives the actuator ring with respect to a reference position at which the linear guide projection 54d of the second sub-lens group frame 54 comes into contact with the rotation preventing surface 51a or 51b (i.e., the position where the rotation of the actuator ring 55 is reversed). For example, the number of pulses of the driving system required to move the focusing lens groups (i.e., the sub-lens groups S1 and S2) from a reference position to a position corresponding to a minimum photographic distance n, to a position corresponding to an infinite photographic distance ∞, and to a position

corresponding to an intermediate photographic distance can be predetermined by taking the leading angles for the focus leading surfaces 55d and 55e into consideration. Accordingly, focusing can be properly carried out in accordance with the object distance information by managing the number of the pulses of the encoder.

Also, in the illustrated embodiment, the slopes of the telephoto side focus leading surface 55d and the wide-angle side focus leading surface 55e of the actuator ring 55 have opposite directions with respect to the circumferential direction thereof, but have the same absolute value, i.e., the slopes both incline forwards in the optical axis direction, and the lug 54e is shaped to be symmetrical with respect to the central axis extending in the middle of the contact surfaces N1 and N2 which are circumferentially spaced apart from each other. Accordingly, focusing can be carried out on the telephoto side in the same manner as on the wide-angle side. This facilitates focusing control.

Figures 17A and 17B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 (i.e., the first sub-lens group S1) and the second sub-lens group frame 54

(i.e., the second sub-lens group S2) are in the mutually distant position at the wide-angle side, and are in a position so as to focus on an object at infinity. Figures 18A and 18B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually distant position on the wide-angle side, and are in a position so as to focus on an object at a minimum distance. Figures 19A and 19B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually close position on the telephoto side, and are in a position so as to focus on an object at infinity. Figures 20A and 20B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually close position on the telephoto side, and are in a position so as to focus on an object at a minimum distance. The first sub-lens group frame 53, the

second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 are shown separated in the optical axis direction in Figures 17A, 18A, 19A and 20A, and are shown in operation in Figures 17B, 18B, 19B and 20B.

Gear teeth 55g are formed over a circumference on the rear-end periphery of the actuator ring 55. As shown in Figures 12, 29 and 30, the gear teeth 55g engage with a series of reduction gears 63a. The series of reduction gears 63a are rotated in either direction by a bi-directional motor 64 which also includes the encoder 64p. The series of reduction gears 63a are held between the front shutter retaining ring 51 and the gear holding ring 56, and the bi-directional motor 64 is held by the rear shutter retaining ring 52. The gear teeth 55g of the actuator ring 55, which are formed over the entire periphery thereof, makes it easy for the three control recesses 55a to engage with the three lugs 54e of the second sub-lens group frame 54 at different relative rotational positions that are separated by 120°.

The lens shutter mechanism 57 and the diaphragm mechanism 58 are mounted on the rear shutter retaining ring 52. In particular, as shown in Figures 12, 15 and 16, the lens shutter mechanism 57 includes a shutter sector support

plate 57a, three shutter sectors 57b, and a shutter drive ring 57c for opening and closing the shutter sectors 57b. The diaphragm mechanism 58 includes a diaphragm sector support plate 58a, three diaphragm sectors 58b, and a diaphragm drive ring 58c for opening and closing the diaphragm sectors 58b. These components are retained in the rear shutter retaining ring 52 by a sector holding ring 57d. The shutter sector 57b and the diaphragm sector 58b include a pair of dowels. One of the dowels is rotatably supported by the support plates 57a and 58a and the other is rotatably fitted to the drive rings 57c and 58c. The lens shutter mechanism 57 opens and closes an aperture formed by the shutter sectors 57b as the shutter drive ring 57c is rotated. The diaphragm mechanism 58 varies the size of an aperture formed by the diaphragm sectors 58b as the diaphragm drive ring 58c is rotated.

Sector gear teeth 57g are formed on a part of the periphery of the shutter drive ring 57c and engage with a series of reduction gears 63b that are sequentially arranged from a shutter drive motor 57m (see Figure 12). When the shutter drive motor 57m is rotated in either direction, the aperture, which has been closed by the shutter sectors 57b, is momentarily opened and is then closed again. In the zoom

lens barrel of the illustrated embodiment, the shutter sectors 57b serve both as a variable diaphragm to provide an aperture of an arbitrary size, and as a shutter. The shutter sectors 57b are electrically controlled so that the size of the aperture of the shutter sectors 57b (aperture value) and the length of time during which the aperture is left opened (i.e., shutter speed) can be varied depending on the exposure, upon the release of the shutter. Furthermore, the diaphragm drive ring 58c includes a lug 58g on the periphery thereof. The lug 58g engages with a diaphragm-controlling cam slot 48s formed on an inner surface of the linear guide ring 48 (see Figure 10). Upon zooming, the linear guide ring 48 and the rear shutter retaining ring 52 (i.e., the diaphragm drive ring 58c) moves relative to each other in the optical axis direction. This causes the lug 58g to follow the diaphragm-controlling cam slot 48s so as to move in the circumferential direction. This in turn causes the diaphragm drive ring 58c to rotate and, as a result, the size of the aperture formed by the diaphragm sectors 58b is varied. The diaphragm sector 58b is provided to restrict the maximum value of the aperture diameter especially in the wide-angle side photographing range, and the degree of opening of the aperture is

mechanically varied in accordance with the amount of extension of the zoom lens barrel.

As shown in Figure 31, the zooming motor 46 for the cam ring 44, the bi-directional motor 64 for the actuator ring 55, and the shutter drive motor 57m for the lens shutter mechanism 57 are controlled by a control circuit (control device) 66. Focal length information 67, which is set by the user (photographer) via a zoom switch or the like, detected object distance information 68, object brightness information 69, information on rotational positions of the cam ring 44, which is provided by a focal length detecting device 46C, and information on rotational positions of the motor 64, which is provided by the encoder 64p, are inputted to the control circuit 66. The zooming motor 46, the bi-directional motor 64 and the shutter drive motor 57m are controlled according to the inputted information so that exposure is carried out under proper exposure conditions in accordance with the predetermined focal lengths. While the shutter sectors 57b serve both as a shutter and as a variable diaphragm, and the diaphragm sectors 58b restrict the aperture diameter upon photographing on the wide-angle side in this embodiment, the diaphragm sectors 58b can be provided as a motor-driven variable diaphragm mechanism.

In the illustrated embodiment, the focal length detecting device 46C (i.e., a rotational position detecting device for the cam ring 44) detects rotational positions of the cam groove 44f which correspond to the connection line CC (see Figure 1), such that the control circuit 66 does not allow the cam ring 44 to stop in this section. If the zoom lens system is provided as a step zoom lens, positions at which the cam ring 44 stops are controlled in a stepwise manner. As described above, while the operations, corresponding to the preset focal length, distance to the object, and the brightness of the object, of the zoom lens barrel (i.e., photographing optical system) having the above-described switching lens group can be completed immediately before the shutter is released, the focal length set by an operator can be confirmed via a separate finder optical system (not shown) that is provided separate from the photographing optical system.

In the zoom lens barrel using the lens barrel for the switching lens groups, positions at which the switching lens group frame 50, the first sub-lens group frame 53, and the second sub-lens group frame 54 stop upon a photographic operation can be practically determined in a stepwise manner along the zoom path.

Note that, while the lens support/drive structure has been described with regard to the first variable lens group 10 shown in Figures 1, 8 and 9, the mechanical construction of the above-described lens barrel is also applicable to the second variable lens group 20 in Figure 2, the second variable lens group 20 in Figure 3, the first variable lens group 10 in Figure 4, the first variable lens group 10 in Figure 5, the first variable lens group 10 in Figure 6, and the first variable lens group 10 in Figure 7 (the first lens L1 is integrally formed with the third lens L3).

In the above-described lens barrel, the first sub-lens group (front sub-lens group) S1 and the second sub-lens group (rear sub-lens group) S2, which together form the switching lens group 10, are supported in the first sub-lens group frame (front lens group frame) 53 and the second sub-lens group frame (rear lens group frame) 54, respectively. The four shift leading surfaces (shift cam surfaces) 53c, provided on the rear end of the first sub-lens group frame 53, cooperate with the four follower projections 54a, provided on the front end of the second sub-lens group frame 54, to move the first sub-lens group frame 53 and the second sub-lens group frame 54 toward each other until they reach the mutually close position on the telephoto side, and

move the first sub-lens group frame 53 and the second sub-lens group frame 54 away from each other until they reach the mutually distant position on the wide-angle side. When the first and the second sub-lens group frames 53 and 54 are in the mutually close position or in the mutually distant position, the follower projections 54a engage either with the follower engaging recesses 53e or the follower engaging recesses 53f. The follower engaging recesses 53e and 53f are formed at the opposite ends of the shift leading surfaces 53c. Namely, the first sub-lens group frame 53 and the second sub-lens group frame 54 are kept engaged while being able to slide relative to one another. The relative positions of the sub-lens group frames 53 and 54 in the axial direction (i.e., the distances between the sub-group frames 53 and 54) when in the mutually close position on the telephoto side or in the mutually distant position on the wide-angle side are determined by the construction that provides the engagement between the sub-lens group frames 53 and 54.

As shown in Figures 10, 15 and 16, a first sub-lens group contact surface (first lens group positioning surface) 53m is provided substantially half-way in the first sub-lens group frame 53 in the axial direction (the

direction parallel to the optical axis of the first sub-lens group S1). The first sub-lens group contact surface 53m is formed as an annular surface facing the front end opening of the first sub-lens group frame 53. The outer diameter of the first sub-lens group contact surface 53m corresponds to the diameter of the first sub-lens group S1, and the inner diameter thereof is smaller than the outer diameter of the rear surface of the first sub-lens group S1. The first sub-lens group contact surface 53m is formed so as to stably receive the rear end surface of the fist sub-lens group S1. A cylindrical portion of the first sub-lens group frame 53 provided in front of the first sub-lens group contact surface 53m has an inner diameter as large as the largest diameter of the first sub-lens group frame contact surface 53m. This allows the first sub-lens group S1 to be inserted in a rearward direction (i.e., toward the first sub-lens group contact surface 53m) through the front end opening of the first sub-lens group frame 53 without causing any interference between the first sub-lens group S1 and the first sub-lens group frame 53.

When the lens barrel is assembled, the first sub-lens group S1 is inserted into the first sub-lens group frame 53 from the front end opening of the first sub-lens group frame

53. The first sub-lens group S1 is inserted into the first sub-lens group frame 53 by a predetermined amount from the front end opening until a portion of the rear surface of the first sub-lens group S1 comes into contact with the first sub-lens group contact surface 53m, and further insertion of the first sub-lens group S1 is prevented. At this stage, the area around the front end of the first sub-lens group frame 53 is heat-sealed to prevent the first sub-lens group S1 from coming out and holds the first sub-lens group S1 in place within the first sub-lens group frame 53. The heat-sealed area of the first sub-lens group frame 53 is denoted by a reference numeral 53n in Figures 10, 15 and 16.

As shown in Figures 10, 15 and 16, a second sub-lens group contact surface (second lens group positioning surface) 54m is provided on the second sub-lens group frame 54 in the vicinity of the front end thereof as viewed in the axial direction (i.e., the direction parallel to the optical axis of the second sub-lens group S2). In contrast to the first sub-lens group contact surface 53m of the first sub-lens group frame 53, the second sub-lens group contact surface 54m is an annular surface facing the rear end opening of the second sub-lens group frame 54. The inner diameter of the second sub-lens group contact surface 54m is smaller

than the outer diameter of the front end of the second sub-lens group S2. The second sub-lens group contact surface 54m is formed so as to stably receive the front surface of the second sub-lens group S2. A cylindrical portion of the second sub-lens group frame 54 to the rear of the second sub-lens group contact surface 54m has an inner diameter that is equal to, or larger than, the largest diameter of the second sub-lens group frame contact surface 54m. This allows the second sub-lens group S2 to be inserted in a frontward direction (i.e., toward the second sub-lens group contact surface 54m) through the rear end opening of the second sub-lens group frame 54 without causing any interference between the second sub-lens group S2 and the second sub-lens group frame 54.

When the lens barrel is assembled, the second sub-lens group S2 is inserted into the second sub-lens group frame 54 from the rear end opening of the second sub-lens group frame 54. The second sub-lens group S2 is inserted into the second sub-lens group frame 54 by a predetermined amount from the rear end opening until a portion of the front surface of the second sub-lens group S2 comes into contact with the second sub-lens group contact surface 54m, and further insertion of the second sub-lens group S2 is

prevented. At this stage, the area around the rear end of the second sub-lens group frame 54 is heat-sealed to prevent the second sub-lens group S2 from coming out and holds the second sub-lens group S2 in place within the second sub-lens group frame 54. The heat-sealed area of the second sub-lens group frame 54 is denoted by a reference numeral 54n in Figures 10, 15 and 16.

As can be clearly seen in Figures 10, 15 and 16, the first sub-lens group contact surface 53m, which determines the position of the first sub-lens group S1 in the optical axis direction with respect to the first sub-lens group frame 53, specifically serves as a positioning surface to define the rearmost position of the first sub-lens group S1. Similarly, the second sub-lens group contact surface 54m, which determines the position of the second sub-lens group S2 in the optical axis direction with respect to the second sub-lens group frame 54, specifically serves as a positioning surface to define the front position of the second sub-lens group S2. In other words, the lens group positioning surfaces are provided such that the rear surface of the first sub-lens group S1 and the front surface of the second sub-lens group S2, which oppose each another, are positioned in the first sub-lens group frame 53 and in the

second sub-lens group frame 54, respectively. Accordingly, the distances V1 and V2 (see Figures 15 and 16) between the first sub-lens group S1 and the second sub-lens group S2 when in the mutually distant position on the wide-angle side and in the mutually close position on the telephoto side are stabilized.

If, unlike the invention, the second sub-lens group S2 were to be inserted rearward and the rear surface of the second sub-lens group S2 abuts a positioning surface provided on the sub-lens group frame, the accuracy in positioning the front surface of the second sub-lens group S2 becomes susceptible to the accumulation of tolerances in lens thickness, making it difficult to stabilize the distances V1 and V2 between the first sub-lens group S1 and the second sub-lens group S2 without providing an adjustment mechanism.

Also, as shown in Figures 10, 15 and 16, the rear end portion of the first sub-lens group frame 53 and the front end portion of the second sub-lens group frame 54 overlap each other. These portions slide with respect to one another when the first sub-lens group frame 53 and the second sub-lens group frame 54 move to assume the mutually close position and the mutually distant position. Smooth sliding

of these sliding portions may be interrupted when they include a sealed region. In the present embodiment, however, the first sub-lens group frame 53 includes a sealed region in the front end portion thereof and the second sub-lens group frame 54 includes a sealed region in the rear end portion thereof. Since the front end portion of the first sub-lens group frame 53 and the rear end portion of the second sub-lens group frame 54 do not overlap each other, sliding of the sub-lens group frames with respect to one another is not affected.

Since the first sub-lens group frame 53 and the second sub-lens group frame 54 are moved relative to one another in the optical axis direction to switch between the mutually close position and the mutually distant position, the distances V1 and V2 between the first sub-lens group S1 and the second sub-lens group S2 are uniquely determined not only by the sub-lens group contact surfaces 53m and 54m but also by the accuracy of the determining device for determining positions of the first sub-lens group frame 53 and the second sub-lens group frame 54 in the optical axis direction when they assume the mutually close position or the mutually distant position. As described above, the follower engaging recesses 53e and 53f formed on the rear

end surface of the first sub-lens group frame 53, together with the follower projections 54a formed on the front end surface of the second sub-lens group frame 54, serve as the determining device for determining relative positions of the first sub-lens group frame 53 and the second sub-lens group frame 54 in the present embodiment. In other words, the mutually close position and the mutually distant position of the first sub-lens group frame 53 and the second sub-lens group frame 54 are determined by the direct engagement of the first sub-lens group frame 53 with the second sub-lens group frame 54.

Thus, the distances V1 and V2 between the first sub-lens group S1 and the second sub-lens group S2 are not affected by the accumulation of tolerances in lens thickness in the lens barrel of the present embodiment since all the elements necessary to determine the distances V1 and V2 are included in the initial formation of the first sub-lens group frame 53 and the second sub-lens group frame 54. In other words, a predetermined distance can be obtained between the first sub-lens group S1 and the second sub-lens group S2 by simply engaging the first sub-lens group frame 53 with the second sub-lens group frame 54 after the first sub-lens group S1 and the second sub-lens group S2 have been

placed into the first sub-lens group frame 53 and the second sub-lens group frame 54, respectively. In this manner, little deviation results in the distances V1 and V2 in different lens barrels. Thus, adjustment mechanism for eliminating the deviation in the distances V1 and V2 in the lens barrels can be dispensed with and a simple support structure for the switching lens group 10 can be achieved.

As the actuator ring 55 is rotated, the first sub-lens group S1 and the second sub-lens group S2, when in the mutually distant position on the wide-angle side, are moved in the optical axis direction while maintaining the distance V1 defined by the first sub-lens group frame 53 and the second sub-lens group frame 54 to provide focusing while the first sub-lens group S1 and the second sub-lens group S2, when in the mutually close position on the telephoto side, are moved in the optical axis direction while maintaining the distance V2 defined by the first sub-lens group frame 53 and the second sub-lens group frame 54 to provide focusing. According to the lens support structure of the present invention, deviation from one lens barrel to another in positions of the sub-lens groups S1 and S2 upon focusing is avoided.

As can be understood from the above description, the

present invention provides a lens barrel with simple construction which can prevent deviation in the distance between the first and the second sub-lens groups that are optically operable when in the mutually close position and in mutually distant position.

However, the present invention is not limited to the illustrated embodiment. For example, while the openings of the first and the second sub-lens group frames 53 and 54 for inserting the first and the second sub-lens groups S1 and S2 are heat-sealed after the sub-lens groups S1 and S2 have been placed in the first and the second sub-lens group frames 53 and 54 in the above-described embodiment, rings may be secured to the openings for preventing the lens groups from coming out.

Furthermore, obvious changes may be made in the specific embodiments of the present invention described herein, such modifications being within the spirit and scope of the invention claimed. It is indicated that all matter contained herein is illustrative and does not limit the scope of the present invention.